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A study of Plagithmysus and Xyleborus bores in relation to Ohia decline

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Final Report of Results

A STUDY OF PLAGITHMYSUS AND XYLEBORUS BORERS IN RELATION TO OHIA DECLINE

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Bernice P. Bishop Museum
Honolulu, Hawaii

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On 30 July 1973, Bishop Museum, under the co-investigation of Drs G. A. Samuelson and J. L. Gressitt, initiated a new phase on the study of the principal insect borers of ohia (Metrosideros collina) trees on the island of Hawaii. This 2-year study was supported by the U.S. Forest Service, coordinated by Mr R. E. Nelson, Director of the Institute of Pacific Islands Forestry, Honolulu. Mr Robert Taylor, field assistant, Bishop Museum, carried out some of the field work, maintained a surveillance on the ohia mortality transects, and was responsible for the laboratory cultures and weather data.

The principal aims were to survey ohia forests within and outside of zones of pronounced ohia forest decline to determine the incidence of the important woodborers: Plagithmysus bilineatus Sharp, Xyleborus simillimus Perkins, and Xyleborus saxeseni (Ratzeburg), and to conduct field and laboratory studies of these borers to clarify their possible roles in relation to the decline of ohia forests. Studies on the systematics of the plagithmysines were continued by Gressitt and initiated on the Xyleborini by Samuelson. The latter study was one of the objectives during Samuelson's stay at the British Museum (Natural History), May-August 1974.

Occurrence and Observations of Borers

Plagithmysus bilineatus Sharp. This cerambycid is endemic to the island of Hawaii and is specific to its host, ohia. Observations of this species took place in the Saddle Area, Puna District, Hawaii Volcanoes National Park, and Kahaluu Forest Reserve. Positive occurrence of this borer was also noted above Laupahoehoe, Kulani, Olaa Forest Reserve, Kau Forest Reserve, and South Kona above Papa.

Saddle Area (Study Areas I-III; Plots 1-6): Highest active infestations of plagithmysine larvae were at Study Area I at 600-700 m elevation. This area has been one of severe decline. Active infestations of larvae were observed in 13% of the trees. The proportion of active and old galleries were about equal in this area, while at higher elevations (1200-1450 m) old galleries far exceeded active ones.

Puna District: The presence of Plagithymsus bilineatus was noted in October 1973, at about 610 m elevation near the USFS transect. There 10 trees (9 dead, 1 declining with $\leq$ 5% green-chlorotic foliage remaining) were positive for Plagithymsus.

Hawaii Volcanoes National Park: In June 1975, 4 dead ohia trees at Sulphur Bank, 1200 m elevation were sampled for plagithmysine galleries. Three trees were positive. In July 1975 at Tree Molds, 1250 m elevation, 15 ohia trees $>$ 125 mm dbh within a 12 m radius had dying upper branches and still-green leaves lower down. All trees had pubescent leaves and a pink-colored cambium. One tree was selected as representative in searching for plagithmysine galleries and was positive: 11 out of 12 x-sections sawed from 4 lineal meters of branch were positive for galleries.

Kahaluu Forest Reserve: The first ground contact with any decline locus in the area was made in August 1973. The site found was at ca 850 m elevation visible from Donkey Mill Road. The site was within a dense mature ohia forest and had distinct boundaries which contained within mostly dead or declining mature trees. Plagithmysus was active

most trees sampled, as noted by recent larval galleries in boles. Some trees with crowns partly intact with still-green foliage had plagithmysine galleries which were callousing over; these galleries were in boles located on or near the cambium. One tree with fully-green foliage slightly off-color located about 100 m outside of the decline locus was positive for galleries, suggesting that the zone was increasing in area.

Another locus at 950 m elevation was reached in October 1973. There 16 ohia were selected for observation: 6 were positive for Plagithmysus of which 4 were still living; by April 1975 one of the latter 4 had died.

Xyleborus simillimus Perkins. This scolytid was treated as X. dubiosus Perkins in our earlier report (Gressitt, Samuelson & Davis 1973). Material reared from ohia was taken to the British Museum (Natural History) by Samuelson and was found to compare closely to the types of X. simillimus. This is an endemic species known thus far from only the island of Hawaii. It was not previously associated with hosts, and the recent records from ohia are the only ones known for this borer. The type locality of X. simillimus was reported as, "Hawaii, above Hilo (1800 ft.)" (Perkins 1900) and it is possible that the locality is in the same vicinity as our present Study Area I.

Saddle Area: X. simillimus occurred through this area and was observed in dead ohia mostly in dead leaf to fine twig stages. The highest incidence was at 715 m elevation (Plot 3) where at least 6.3% of all trees in the plot were positive for this scolytid. In the higher plots the incidence was lower, being 1.2% and 1.5% for the 1270 m and 1450 m sites respectively.

Kahaluu Forest Reserve: In contrast to the Saddle Area, the present of this scolytid in both the 850 m and 950 m decline loci was remarkable, because declining ohia were being attacked. Ohia with still-green foliage had active infestations of this borer. Trees positive for this scolytid also had active galleries of Plagithmysus bilineatus. The incidence of the scolytid was not determined, but casual observations indicated that it was probably present in most or the large severely declining to recently dead ohia.

Xyleborus saxeseni (Ratzeburg). This widespread species was noted in the Saddle Area in association with X. simillimus and also in fire-damaged ohia on Byron Ledge, Hawaii Volcanoes National Park.

Byron Ledge: This site was revisited in August 1973, 13 months since the first visit. Many of the ohia which had completed burned foliage were recovering. One of the trees which had been attacked by X. saxeseni was showing good recovery with new flushing along stem to crown.

Studies of Biologies

Rearings of Plagithmysus bilineatus were continued on Harley's Diet, an artificial larval food preparation. The cultures were maintained by Taylor and kept in the insectary on Saddle Road during the first year of the study period. Some 122 cultures were maintained, with about 75% carried over from the initial study period. These were kept under

moister conditions with lids on vials and that resulted in 34% success in rearing larvae through to adults. The newer material was kept under conditions closer to atmospheric relative humidity with lids removed from vials resulting in 52% success.

Over a 14-month period ending April 1974, Taylor measured stadia of various larval instars and the pupal stage in over 100 individuals. Larval instars could not always be identified with certainty, especially in the first two or three instars. Larvae were usually collected during their earlier instars from the field. Measurements of stadia are reported here as mean days:

antipenultimate larva	65 days
penultimate larva	39 days
ultimate larva	36 days
pupa	37 days

With additional time required for egg stage and the first one or two larval instars, the cycle of P. bilineatus would be somewhat over 6 months under laboratory conditions. Season and locality or elevation should also have bearing on the length of the cycle.

Xyleborus simillimus was reared from log sections collected at 600-700 m and 1270 m elevations in the Saddle Area and at 850 m in Kahaluu Forest Reserve.

Gallery conformation appears to be largely confined to a horizontal plane with the entrance more or less perpendicular to tree surface for the first 10-15 mm, becoming gently arcuate with branching; branches often parallel to tree circumference for more or less one-half their length before bending toward the center. Galleries in 100 mm dbh trees frequently reach the center.

Ohia Mortality Transects

Relative changes in health classes of ohia in Study Area I (ohia scrub) S of Saddle Road at 600-700 m elevation; Study Area II (ohia scrub), ca 1 km S of Saddle Road, E of Tree Planting Road at 1270 m; Study Area III (ohia forest), ca 2 km S of Saddle Road, E of Tree Planting Road at 1270 m were observed by Mr R. Taylor during the period June 1973 to June 1975.

Study Area I (n = 54 trees): In the period June 1973-March 1974, 58% of the trees increased in vigor; 24% showed reduced vigor with conspicuous crown loss; 19% remained unchanged. In the period April 1974-June 1975, 13% increased in vigor; 48% decreased; 39% remained unchanged.

Study Area II (n = 40 trees): In the period June 1973-March 1974, 70% of the trees increased in vigor; 18% decreased; 13% remained unchanged. In the period April 1974-June 1975, 25% increased in vigor; 38% decreased; 38% remained unchanged.

Study Area III (n = 44 trees): In the period June 1973-March 1974, 73% of the trees increased in vigor; 9% decreased; 18% remained unchanged. In the period April 1974-June 1975, 9% increased in vigor; 55% decreased; 36% remained unchanged.

Trends, while remaining similar in all study areas, differed over the two periods. During the former period there was a decided increase in vigor of trees; during the latter period there was a pronounced decrease in tree vigor; levels of trees remaining unchanged was more or less constant during both periods.

Kahaluu Forest Reserve Study Area: A short transect of 16 ohia trees was put in by Samuelson and Taylor in Ocotober 1973. The site is near Donkey Mill Road at ca 950 m elevation in one of the upper decline loci. The transect is perpendicular to the USFS transect at the same site. This is a closed ohia forest with generally smaller trees than at the lowest decline locus at 850 m. The 16 trees sampled fell equally into two dbh categories: 70-95 mm and 150-250 mm. Plagithmysus bilineatus and Xyleborus simillimus were both active on trees in this area.

October 1973: 10 trees had more or less intact green crowns; 3 were alive with 20-50% crowns green; 1 was alive with no crown; 1 was nearly dead with less than 25% crown; 2 were dead. Plagithmysus bilineatus was present in 6 trees including the 2 dead ones; Xyleborus simillimus was present in 2 dead trees and 1 nearly dead tree.

January 1974: Some of the trees with poor crowns were producing new leaves on boles; 1 tree which had a poor crown plus plagithmysine galleries earlier now had new emergence holes of the borer. The proportion of living, declining, and dead trees remained about the same.

March 1974: 3 trees were dead (Taylor).

April 1975: Of the 13 living trees observed in March 1974, 11 remained in more or less healthy condition, 1 had died, and 1 was in severe decline (Taylor).

Plots

Five new circular plots (plots 2-6) each 1/25 ha in area and one square transect describing the perimeter of 1/2.5 ha ("plot" 1) were established to compare the incidence of living, declining, and dead trees per plot, growth postures and certain phenotypic characters of individual trees and associated information on woodborers and their impact on individual trees. Plot locations are shown in Figures 1 and 2. Plots included all living and standing dead trees over 14 dm in height whose stems occurred within the zone of the circular plot or near the transect centerline (described below). Every tree evaluated was assigned a number, tagged, and graded on a corresponding data card. Data were then transferred from the data cards to IBM cards and computerized for contingency analyses of certain categories and a printout of simple percentages of scores per plot.

Data card format (Figure 3): Single/cluster categories identify ohia growing as individual trees or as clusters arising from a common base, usually a previously fallen tree; dbh is recorded and assigned to dbh classes later; percentage of green crown is checked in the appropriate region of the scale; foliage color or stage of decline or decay are noted: green and gr+flag are graded as more or less healthy, gr-yellow and

r-brown are graded as declining, and the remaining pertain to dead trees; leaf-type and underbark color are noted; Plagithmysus and Xyleborus associations are noted as negative, questionable, or positive and when positive whether the occurrence of the borer was presently active, questionably active, or had occurred in the past; provisions are included for numbers of larvae and pupae, emergence holes and occurrence of parasites. Tree characteristics are summarized in Table 1.

Plots: Plot 1 (a square-shaped transect). Saddle Area at 1270 m elevation, located S of Saddle Road and E of Tree Planting Road (Figure 2). This is a transect describing the perimeter of 0.4 ha, being 63.25 m long on each leg, taking in every tree on or overhanging 1 m on each side of the centerline. Substrate mostly broken with aa flows interspersed with pahoehoe; terrain undulating to sloping. Understory open and occupied by low-growing species including Cladium (uki sedges), Dicranopteris (uluhe ferns), Sadleria (ama'uma'u ferns), Vaccinium (ohelo), Coprosma (kukae-nene), and various grasses. Intervals between trees containing larger species include Coprosma (pilo), Cheirodendron (olapa), and Styphelia (pukiawe). Ohia scrub (n = 140): leaf phenotype predominantly pubescent, 88%; underbark coloration orangish-pinkish in 50% and whitish-greenish in 38%. Ohia dbh sizes predominantly of smaller classes, with only 2% of trees over 150 mm in dbh.

Plot 2. This circular plot is located within the perimeter of the transect described above (Figure 2). Ohia scrub (n = 98): characteristics of trees similar to those or Plot 1, mentioned above.

Plot 3. Saddle Area at 715 m elevation, S of Saddle Road (Figure 1). Substrate mostly broken aa flows interspersed with pahoehoe; terrain gently sloped. Understory and intervals between ohia trees mostly open and occupied by low-growing plants including Cladium, Dicranopteris, and various grasses. Ohia scrub (n = 78): leaf phenotype glabrous in 38% and pubescent in 32%; underbark coloration orangish-pinkish in 51% and whitish-greenish in 15%. Ohia dbh predominantly 12-75 mm dbh, 78%; 1% of trees present over 150 mm in dbh.

Plot 4. Saddle Area at 1450 m elevation, 100 m W of small puu S of Saddle Road (Figure 2). Substrate mostly exposed pahoehoe; terrain flat to undulating. Understory quite open with Cladium and some Dicranopteris; also some Coprosma (kukae-nene), Dubautia, and Styphelia. Ohia scrub (n = 64): almost entirely of pubescent-leaved phenotype; underbark coloration orangish-pinkish in all trees. Ohia dbh sizes predominantly of smaller classes; no trees over 150 mm present. In July 1975 this plot had the highest composition of living ohia (100%) of all the plots.

Plot 5. Saddle Area at 1450 m elevation, a kipuka of a small puu S of Saddle Road (Figure 2). Substrate broken in part, but with soil; terrain quite irregular with moderate slopes in part. A dense, wet forest of mixed trees; understory closed, with Cibotium (hapu'u tree ferns) and associates. Ohia forest, mature (n = 74): leaf phenotypes glabrous in 41% and pubescent in 30%; the remainder unobservable or dead without leaves. Underbark coloration predominately orangish-pinkish, 86%. This is the only plot to have dbh classes with largest class, > 150 mm commonly represented, 27%; smaller trees still predominate, with 25-150 mm dbh trees making up 59%.

Plot 6. Saddle Area at about 1450 m elevation, S of Plot 5 (Figure 2). Substrate broken and sloping. Understory mostly open, with Cladium and Dicranopteris. Ohia

==rub (n = 166): leaf phenotypes predominantly pubescent, 89%; underbark coloration orangish-pinkish in 58% and whitish-greenish in 31%; Ohia dbh classes fairly evenly distributed from ≤ 12-150 mm; 2% of trees exceeding 150 mm in dbh.

Discussion: Contingency analyses of pooled data from all plots reflected no particular trend in relating active or post occurrences of Plagithmysus to (1) host leaf-type (pubescent or glabrous -- Cramer's V = 0.19285), or (2) host underbark color (Cramer's V = 0.12848).

Considering the six plots as points along an altitudinal gradient on the windward slopes of the island, with Plot 3 at 715 m, Plots 1-2 pooled at 1270 m, and Plots 4-5 pooled at 1450 m, the proportion of living, declining, and dead ohia varied with elevation, as did the positive occurrences of Plagithmysus on living, declining, and dead hosts. These proportions are shown in a histogram (Figure 4).

Climatic Data

Instruments were set up at Study Areas II and III, 1-2 km S of Saddle Road, E of Tree Planting Road, ca 1270 m elevation.

Hygrothermograph: A hygrothermograph was set up in the forest transect (Study Area II) in May 1974. Problems resulting from worn parts and the need to recalibrate instrument caused some gaps (NA) for certain months.

		TEMPERATURE (°F)			HUMIDITY (relative)	
	MONTH	HIGH	LOW	MEAN	HIGH	LOW
1974	May	73	41	57	100	NA
	June	74	37	55.5	100	NA
	July	NA	NA	NA	NA	NA
	August	73	32	52.5	100	NA
	September	72	39	55.5	100	NA
	October	NA	NA	NA	NA	NA
	November	NA	NA	NA	NA	NA
	December	NA	NA	NA	NA	NA
1975	January	NA	NA	NA	NA	NA
	February	70	39	54.5	100	8
	March	67	42	54.5	100	42
	April	68	47	57.5	100	51
	May	77	43	60	100	42
	June	75	47	61	100	38
	July	75	48	61.5	100	46
	August	75	51	63	100	50

in gauges: A PA 1000 rain gauge was placed in ohia scrub (Study Area II) in April 1975. Later in the same month a Tru-check rain gauge was placed next to the preceding one and another Tru-check gauge was placed in ohia forest (Study Area III).

DATE	USFS GAUGE	FOREST TRU-CHECK	SCRUB TRU-CHECK	AVERAGE WEEKLY RAINFALL
April 25	4.43	NA	NA	4.43
May 2	1.97	1.80	1.75	1.84
May 8	3.30	3.15	2.80	3.08
May 16	0.86	0.69	0.70	0.75
May 23	0.45	0.34	0.36	0.38
May 30	0.55	0.51	0.50	0.52
June 6	0.65	0.44	0.46	0.52
June 13	1.77	1.57	1.60	1.65
June 20	0.90	0.62	0.80	0.77
June 27	0.81	0.67	0.71	0.73
July 4	1.24	1.15	1.20	1.19
July 11	0.68	0.53	0.53	0.58
July 18	2.70	2.70	2.40	2.60
July 25	1.64	1.45	1.40	1.50
August 1	NA	NA	NA	NA
ugust 6	1.77	1.75	1.55	0.99
igust 11	0.52	0.49	0.46	0.69
ptember 5	4.87	4.45	3.50	1.30

Reference Cited

Perkins, R. C. L. 1900. Coleoptera II. Coleoptera, Rhynchophora, Proterhinidae, Heteromera and Cioidae. Fauna Hawaiiensis 2(3): 117-270, plates 7-10.

Appendix 1

A List of Hawaiian Xyleborini with Keys to Species

This section was extracted from a manuscript entitled, "A Synopsis of Hawaiian Xyleborini" which is being prepared by Samuelson for eventual publication in the Proceedings of the Hawaiian Entomological Society. It was thought that the inclusion of the keys in the present report would make them available for immediate use, thereby providing time for emendations or corrections as may be necessary.

The Hawaiian scolytid fauna is characterized by a largely adventive assemblage of species. Although affinities have yet to be determined for many species, a good portion of the members of Xyleborus are certainly endemic. This is particularly evident because of the presence of several complexes of species throughout the archipelago which are closely interrelated but distant from congeners from other island groups or continents. The systematics of the group requires further investigation, for many species were described from one to several examples, usually comprising one sex. Moreover, little or no biological information has been gained for many species.

The Xyleborini may be separated from other members of the family represented in Hawaii by the following combination of characters:

1 Antennal club obliquely truncate, distinctly thickened basally; surface densely pubescent only on one side.

2 Metatibia broad: dilated to slightly beyond middle before narrowing to apex.

The other groups represented in Hawaii either have the antennal club rather evenly compressed with both surfaces more or less equally pubescent, or if the club is obliquely truncate, then the metatibia is slender.

The present list of Hawaiian Xyleborini, even though reflecting recent literature, should be regarded as provisional until the group is fully revised. Invalid names of species are indented under the appropriate species. An asterisk (*) indicates a new change in status which will take effect upon publication of the synopsis.

Genus Xylosandrus Reitter

compactus (Eichhoff)
    morstatti (Hagedorn)
morigerus (Blandford)

Genus Xyleborus Eichhoff

affinis Eichhoff
    mascarensis Eichhoff
agamus Perkins
dubiosus Perkins
exsectus Perkins
ferrugineus (Fabricius)
    confusus Eichhoff
    insularis Sharp
fornicatus Eichhoff
hawaiiensis Perkins
ignobilis Perkins
kauaiensis Perkins
lanaiensis Perkins
littoralis Perkins
mauiensis Perkins
molokaiensis Perkins
nuuanus Schedl
oahuensis Perkins
oahuensis scabratus Schedl
perforans (Wollaston)
    immaturus Blackburn
    kraatzi Eichhoff
    pubescens Perkins
    testaceus (Walker)
rugatus Blackburn
saxeseni (Ratzeburg)
    frigidus Blackburn *
    pseudoangustatus Schedl
semigranosus Blandford
similis Ferrari
simillimus Perkins
spinulosus Blandford
    spinosulus Schedl
tantalus Schedl *
    obliquus Sharp *
vulcanus Perkins
    adspersus Schedl
    pacificus Nunberg
    truncatus Sharp

Key to Genera of Hawaiian Xyleborini

1. Procoxae widely separated; length in ♀♀ Hawaiian species <1.95 mm ..... Xylosandrus

   Procoxae contiguous or narrowly separated; length in ♀♀ Hawaiian species 1.95 mm or longer ..... Xyleborus

Key to Hawaiian Species of Xylosandrus -- ♀♀

1. Elytral declivity abrupt, becoming apparent before middle of elytron; epipleuron strongly sinuate in lateral view; body slightly stouter: about 0.52 X as broad as long; dorsum orange-fuscous; length 1.6-1.9 mm [S Asia, Pacific] ..... morigerus

   Elytral declivity gradual, becoming apparent behind middle of elytron; epipleuron moderately sinuate in lateral view; body slightly narrower: about 0.48 X as broad as long; dorsum dark fuscous; length 1.6-1.8 mm [pantropical] ..... compactus

Key to Hawaiian Species of Xyleborus -- ♀♀

1. Body length <3.0 mm, commonly 2.7 or less (if between 2.85-3.1 mm, try both bracts of couplet for best fit) 2
Body length 3.0 mm or more 13

2. Body form robust: 0.41 X or more as broad as long 3
Body for slender to moderate: 0.40 X or less as broad as long 4

3. Elytral striae quite evident apically; interstices apically shining to subshining, smooth to alutaceous; length 2.0-2.6 mm [S Asia, Australia, Pacific] ..... fornicatus
Elytral striae not evident apically; surface apically opaque, dull; length 2.2-2.4 mm [Africa, S Asia, Pacific] ..... semigranosus

4. Elytral declivital area opaque, dull 5
Elytral declivital area shining to subshining, smooth to alutaceous even if closely punctulate 6

5. Pronotal disc with basal region opaque; elytral apex with tubercles exceeding curvature of margin as viewed dorsally; length 1.95-2.35 mm [widespread] ..... saxeseni
Pronotal disc with basal region smooth to alutaceous; elytral apex with tubercles not exceeding curvature of margin; length 2.2-2.4 mm (cf. perforans, couplet 12) [pantropical] ..... affinis

6. Elytron briefly rounded apically: curvature confined to apical <0.20, commonly about 0.15 7
Elytron moderately rounded apically: curvature confined to apical 0.20 or more 8

7. Pronotum with anterior margin subtruncate, briefly convex; interstice 1 with 1 tubercle distinctly larger than others placed near middle on declivity; elytral declivital area smooth, interstices not punctulate; length 2.3-2.5 mm [SE Asia, Australia, Pacific] ..... similis
Pronotum with anterior margin moderately convex; elytral interstice 1 with 2 tubercles distinctly larger than others placed above and below on declivity; declivital area alutaceous, interstices closely punctulate; length 2.4-3.1 mm, commonly < 3.0 [endemic: Hawaii, Maui, Lanai, Oahu] ..... vulcanus

8. Elytron with apical outline convex, at most with small tubercles barely exceeding curvature of apical margin 9
Elytron with apical outline interrupted by large spines far exceeding curvature of apical margin; length 2.3 mm ± [Central America, Hawaii] ..... spinulosus

Summit of pronotal disc near middle; procoxae contiguous 10
Summit of pronotal disc well behind middle; procoxae separated 12

10. Elytral declivital area with largest tubercles on interstices 1 and 3 of subequal size 11
Elytral declivital area with tubercle on interstice 3 much larger than others; length 2.3-2.7 mm [pantropical] ..... ferrugineus

11. Pronotal disc with basal region smooth-alutaceous; length 2.2-2.4 mm (cf. affinis, couplet 6) [pantropical] ..... perforans
Pronotal disc with basal region dull, finely granulate; length 2.45-2.6 mm [endemic: Oahu] ..... rugatus

12. Pronotum with denticles prominent anteriorly, interrupting curvature of anterior margin; length 2.35-2.5 mm [endemic: Hawaii] ..... ignobilis
Pronotum with denticles not prominent anteriorly; length 2.55-2.7 mm [endemic: Oahu] ..... nuuanus

13. Elytral declivital area shining to subshining: smooth to alutaceous even if closely punctulate 14
Elytral declivital area opaque: granulate, dull; length 2.9-4.15 mm ..... endemic complex:
[Hawaii -- 2.95-3.0 mm, Oahu] ..... hawaiiensis
[Kauai -- 3.6-3.8 mm, Hawaii, ?Maui, ?Oahu] ..... kauaiensis
[Maui -- 2.9-3.25 mm] ..... mauiensis
[Molokai -- 3.95-4.15 mm] ..... molokaiensis

14. Elytron briefly rounded apically: curvature confined to apical <0.20 of elytron 15
Elytron moderately rounded apically: curvature confined to apical 0.20 or more of elytron; length 2.85-3.65 mm [endemic: Oahu, Hawaii] ..... tantalus

15. Elytral declivital area with distinct tubercle on interstice 3 16
Elytral declivital area lacking distinct tubercle on interstice 3, sometimes with a small granule at most; length 3.0-3.35 mm [endemic: Hawaii] ..... simillimus

16. Pronotal disc transversely subangulate in profile; length 3.0-3.35 mm [endemic: Maui, Oahu, Kauai] ..... dubiosus
Pronotal disc transversely convex in profile; length 3.35-3.7 mm ..... endemic complex:
[Lanai -- 3.35-3.6 mm, Oahu, ?Hawaii] ..... lanaiensis
[Oahu -- 3.6-3.7 mm] ..... oahuensis

Key to Hawaiian Species of *Xyleborus* -- known ♂♂

Sexual dimorphism is well developed in this genus and is carried to an extreme in certain larger sized endemic species. Sexes remain poorly associated for most species collected in Hawaii and remain unassociated in many of the endemic species. Of the endemics, five species-group names are based on ♂ holotypes and are identified by an asterisk (*) in the key. Three of these species have not been associated with females, yet probably are synonymous with females of other described species. Sexes of *vulcanus* Perkins were associated by Wood (1966: 32), who synonymized this species with *truncatus* Sharp; however, the latter name is a junior homonym and thereby validates the available name *vulcanus*. Sexes of *oahuensis* Perkins were associated by Schedl (1941: 113), who went on to describe the male as a variety. On the basis of sexual dimorphism the name *scabratus* has no standing, but the limits of the *oahuensis* complex are not well defined.

1. Pronotum with anterior margin entire 2
   Pronotum with anterior margin emarginate sublaterally 8

2. Scutellum flattened 3
   Scutellum carinate; length 1.5 mm [widespread] ..... *saxeseni*

3. Pronotum with anterior margin broad, subtruncate to convex 4
   Pronotum with anterior margin narrowed, sides converging to briefly rounded apex; length 2.0-2.1 mm [endemic: Lanai] ..... *agamus* *

4. Elytron with tubercles or granules on declivital area (preapical portion) 5
   Elytron lacking tubercles or granules on declivital area 7

5. Elytral declivital area with interspaces 1 and 3 with equal-sized tubercles 6
   Elytral declivital area lacking tubercles on interspace 1 and possessing a large tubercle at middle on interspace 3; length 2.0-2.3 mm [pantropical] ..... *ferrugineus*

6. Elytral declivital area opaque; length 1.7-2.0 mm [pantropical] ..... *affinis*
   Elytral declivital area shining; length ?1.7-2.0 mm [pantropical] ..... ?*perforans*

7. Elytron with longitudinal depression occupying most of puncture rows 1 and 2; length 1.6 mm [S Asia, Australia, Pacific] ..... *fornicatus*
   Elytron lacking longitudinal depression occupying most of puncture rows 1 and 2; length 1.65-1.8 mm [Central America, Hawaii] ..... *spinulosus*

8. Pronotum with extreme apex acute or briefly convex in outline 9
   Pronotum with extreme apex concave in outline 12

Elytron ± briefly rounded apically: curvature confined to apical 0.25 or less of elytron 10
Elytron moderately rounded apically: curvature confined to apical 0.26 or more of elytron (actually about 0.34 in specimen examined); length 3.15 mm [endemic: Oahu, Hawaii] .... ?tantalus

10. Pronotum with extreme apex acute or briefly rounded 11
Pronotum with extreme apex obtusely angulate; length 3.0 mm [endemic: Hawaii] ..... simillimus

11. Elytral declivital area with distinct tubercles on interstice 3; length 2.35-2.8 mm ..... endemic complex:
[Lanai, Oahu -- 2.35 mm, ?Hawaii] ..... lanaiensis
[Molokai -- 2.8 mm] ..... littoralis *
[Oahu -- 3.4 mm] ..... oahuensis scabratus *
Elytral declivital area lacking distinct tubercles on interstice 3; length 2-35-2.45 mm [endemic: Hawaii, Maui, Lanai, Oahu] ..... vulcanus *

12. Elytral declivital area flattened; length 2.75-3.65 mm endemic complex:
[Kauai, Hawaii -- 3.6-3.65 mm, ?Maui, ?Oahu] ..... kauaiensis
[Maui -- 2.75 mm] ..... mauiensis
Elytral declivital area convex; length 3.15-3.35 mm
[endemic: Maui] ..... exsectus *

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Appendix 2

Resume of the Plagithmysine Borers

Plagithmysine is a term used to denote the major group of cerambycid beetles endemic to Hawaii. It had been considered the equivalent of a sub-tribe, but has been reduced to a single genus (Plagithmysus) recently. The group is large, however, with at least 136 species, all evolved from a single ancestor (from W North America) which colonized the Hawaiian group early in its history -- a few million years ago. The group has evolved in diverse directions (insular radiation). Species are highly host-specific and are known to be associated with 35% of the genera and 52% of the families of plants having endemic woody species in Hawaii. In general the plagithmysines bore in living trees under stress. Some species merely help prune excess branches, wnile others damage the cambium area of trunks and major branches of living trees. With some exceptions, the more common native tree species have more plagithmysine associations than do the less common trees. Thus koa and ohia serve as hosts of more species of plagithmysines (usually 1 or 2 species on each island, each species endemic to a single island) than do most other single tree species. In general more abundant tree species have more species of insects associated with them (Southwood 1960). However, the genus Pelea (several species) hosts more kinds of plagithymsines than does Metrosideros. Although Metrosideros is the pioneer forest element on lava flows, Acacia koa hosts more than twice as many species as ohia. This may be in part because the plagithmysines in general prefer forests which are not too densely shady, which is often the case with old ohia forests in wet areas. This factor has a definite revelance to ohia decline, as Plagithmysus bilineatus is more abundant in sparse stands of ohia, besides being favored by the occurrence of unhealthy or damaged trees. Thus ohia decline has been responsible for great population increases of this borer, unless the decline has resulted from boring by this beetle following slashing, felling, or road construction.

There is a record for a second species of plagithmysine in ohia on the island of Hawaii, but this has not been corroborated in recent years. There are two abundant species in koa, the smaller one restricted to terminal smaller branches.

A report is in press on the evolution and host-relationsnips of the plagithmysines. A bibliographic check-list summarizing all reported information is in preparation.

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Table 1. Summary of sample population characteristics of trees by plot. Shown as %.

OHIA	PLOT 1	PLOT 2	PLOT 3	PLOT 4	PLOT 5	PLOT 6
[illegible] habit						
[illegible]gle	92.1	66.3	88.4	81.2	93.2	69.6
[illegible]ter	7.8	32.6	10.2	18.7	6.7	29.1
dbh						
<12 mm	40.0	23.4	7.6	31.2	4.0	15.4
12-25 mm	41.4	52.0	43.5	26.5	9.4	24.4
26-75 mm	13.5	17.3	34.6	32.8	18.9	32.7
76-150 mm	2.8	6.1	12.8	9.3	40.5	23.8
>150 mm	2.1	0	1.2	0	27.0	2.3
crown						
0	14.2	12.2	30.7	0	10.8	10.7
5-20	4.2	0	5.1	3.1	5.4	10.7
25-40	3.5	4.0	5.1	12.5	8.1	6.5
45-60	7.8	5.1	6.4	20.3	27.0	25.0
65-80	27.8	54.0	39.7	31.2	32.4	33.9
85-100	41.4	21.4	12.8	32.8	6.7	11.3
leaf-type						
pubescent	87.8	79.5	32.0	98.4	29.7	88.6
glabrous	1.4	8.1	38.4	1.5	40.5	0
crown						
[illegible]en	77.8	71.4	41.0	100.	67.5	47.0
[illegible]+ flag	1.4	2.0	24.3	.0	12.1	29.7
[illegible] yellow	5.0	11.2	2.5	0	1.3	4.7
gr-brown	2.8	2.0	1.2	0	0	5.9
brown-gray	0	2.0	0	0	1.3	2.3
F twig/pods	1.4	0	16.6	0	0	6.5
heavy twigs	1.4	1.0	3.8	0	0	1.1
branches	3.5	0	1.2	0	0	0
snag	5.0	9.1	3.8	0	8.1	1.1
cambium						
white-greenish	37.8	33.6	15.3	0	4.0	30.9
orangish	0	7.1	6.4	32.8	10.8	25.5
pinkish	50.0	46.9	44.8	67.1	75.6	32.1

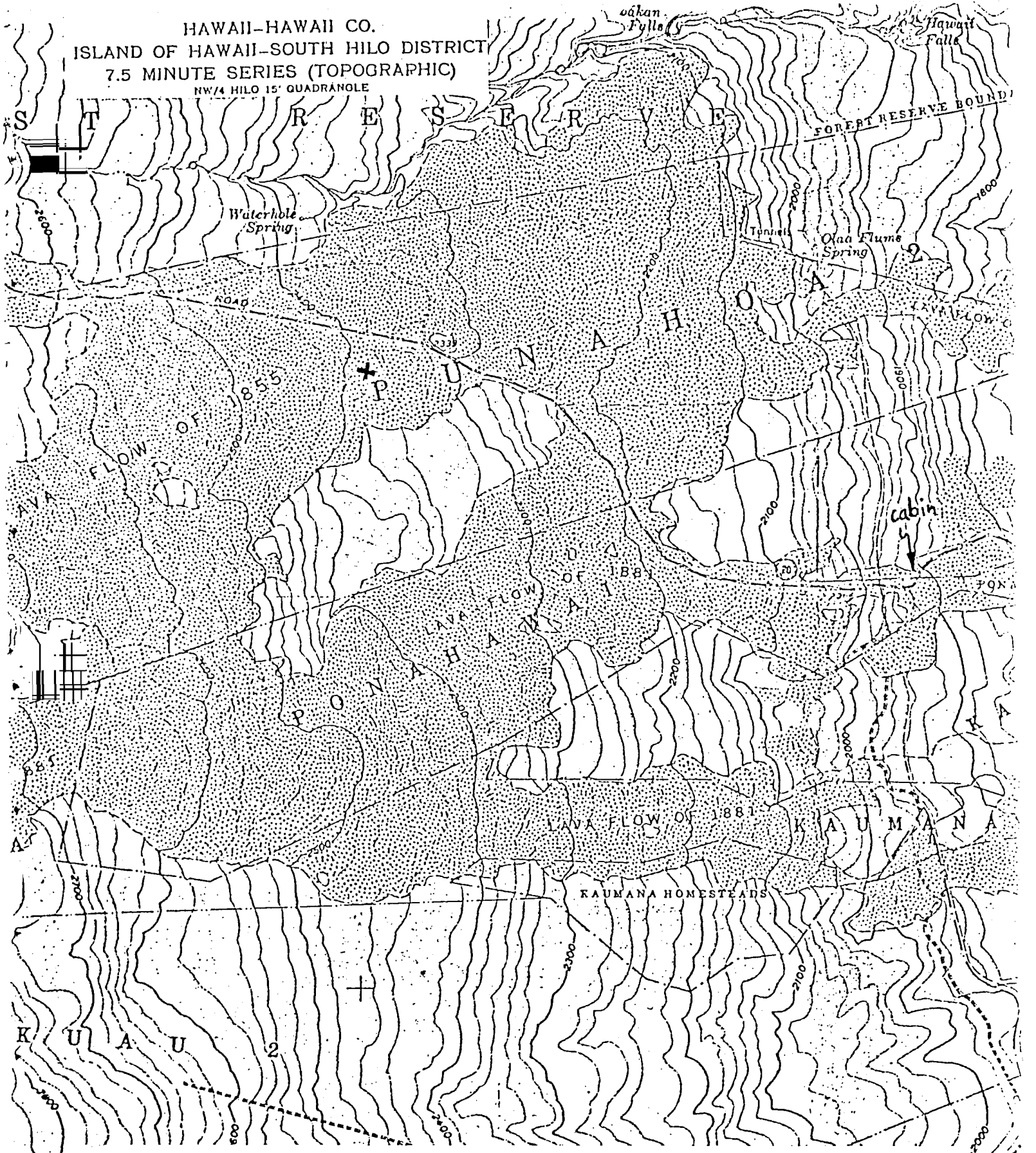

Figure 1. Map showing location of Study Area I and Plot 3 (vicinity of X 8 cm from top and 13.75 cm from right margin). Location of cabin (insectary) is shown 2.5 cm from right margin. North faces upper margin.

Figure 2. Map showing location of Study Area II and Plots 1-2 (vicinity of X 6.75 cm from top and 8.75 cm from right margin); Study Area III (6.5 cm from top and 7.5 cm from right margin) and Plots 4-6 (ca 8 cm from bottom and 6 cm from right margin). North from left margin.

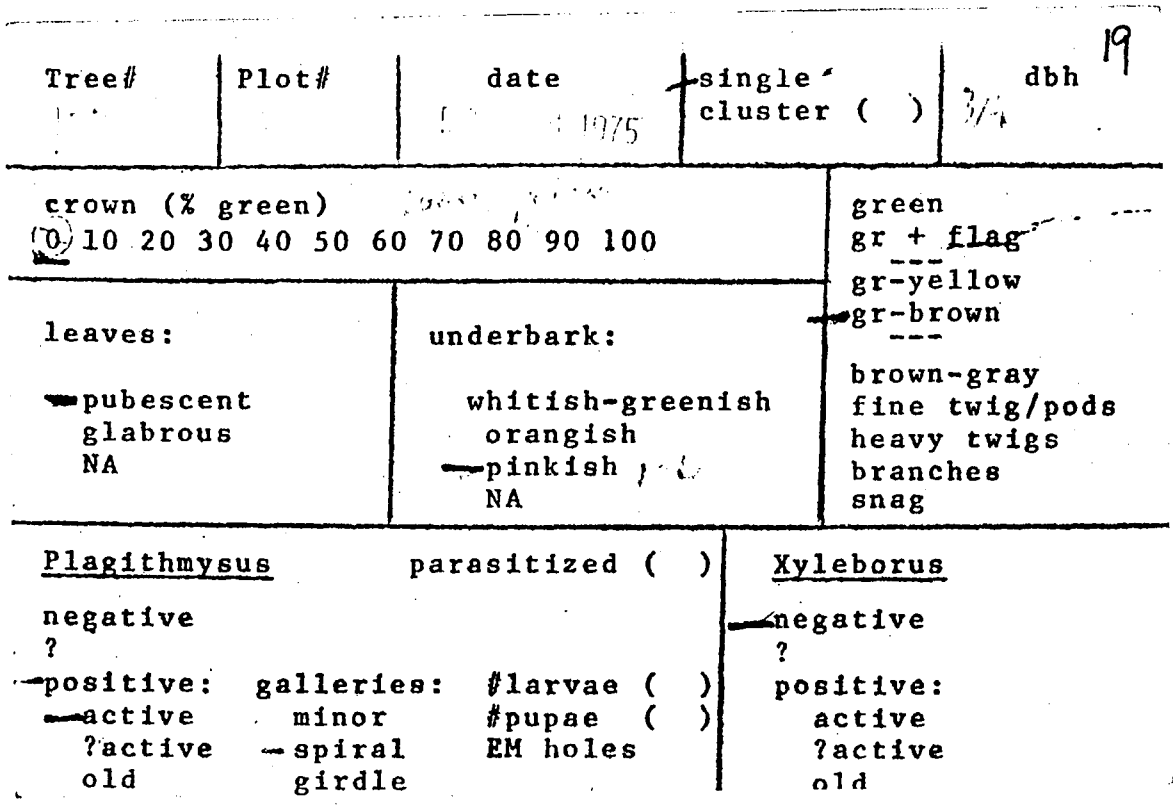

Figure 3. Data entry card. The card figured is for tree #17 in Plot 1, a tree in decline. It is a single-stemmed tree with dbh of 19 mm; crown lacking but some green leaves present lower down; most leaves faded to greenish-brown; leaves pubescent; cambium pale pinkish; active boring by Plagithmysus; Xyleborus absent.

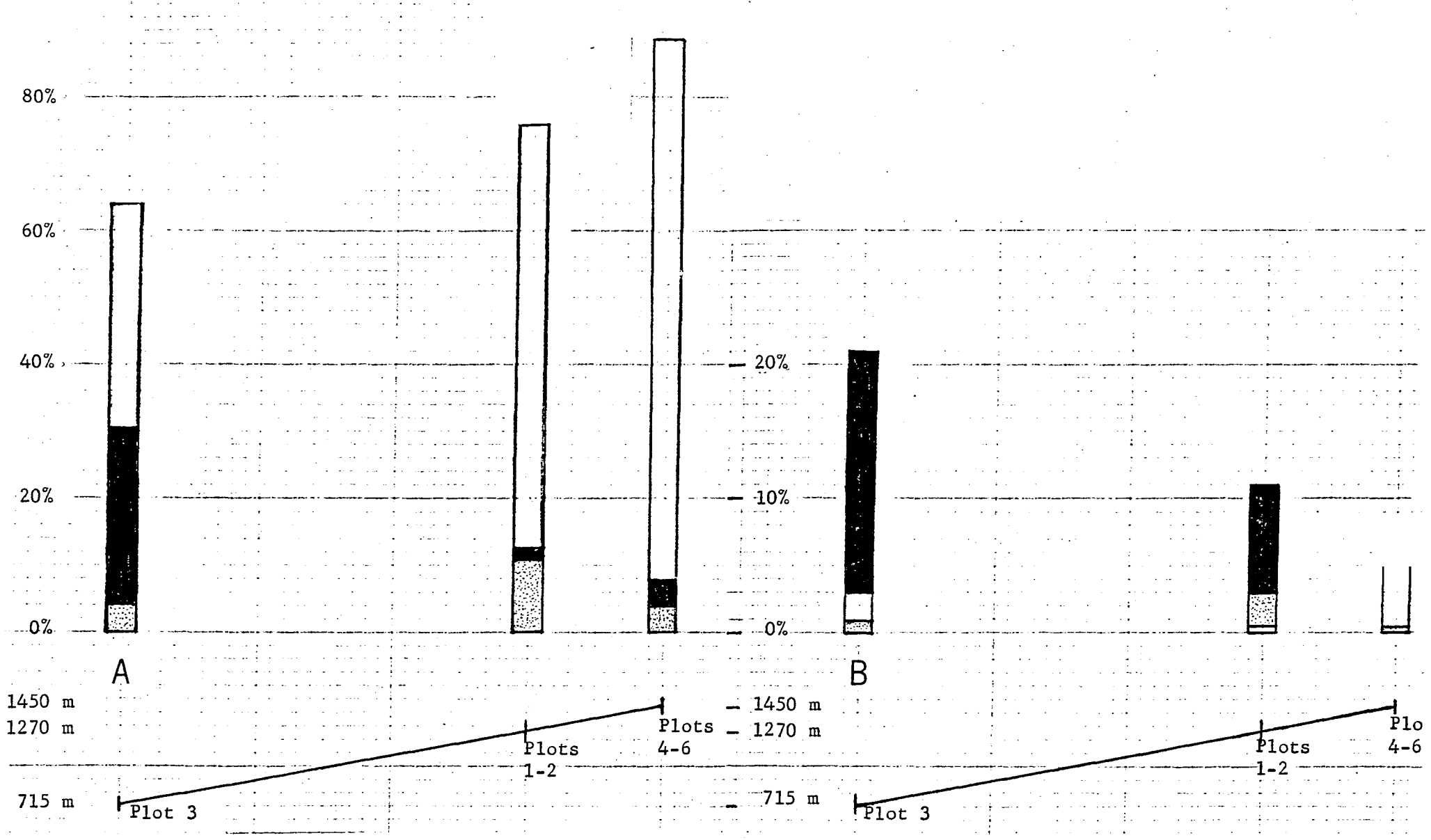

Figure 4a, b. Histogram showing percentage of living (open), declining (stippled), dead (black) ohia trees in pooled plots grouped by elevation; vector at bottom of each subfigure shows altitudinal gradient with points where plots are located: 4a treats the total tree population; 4b treats only the trees positive for borings of Plagithmysus bilineatus.